Large-scale Additive Manufacturing for Exploration

SME Webinar

February 1, 2022

Paul Gradl
Senior Propulsion Engineer

THE POWER OF SLS AND ORION

ORION

The only spacecraft capable of carrying and sustaining crew on missions to deep space, providing emergency abort capability, and safe re-entry from lunar return velocities

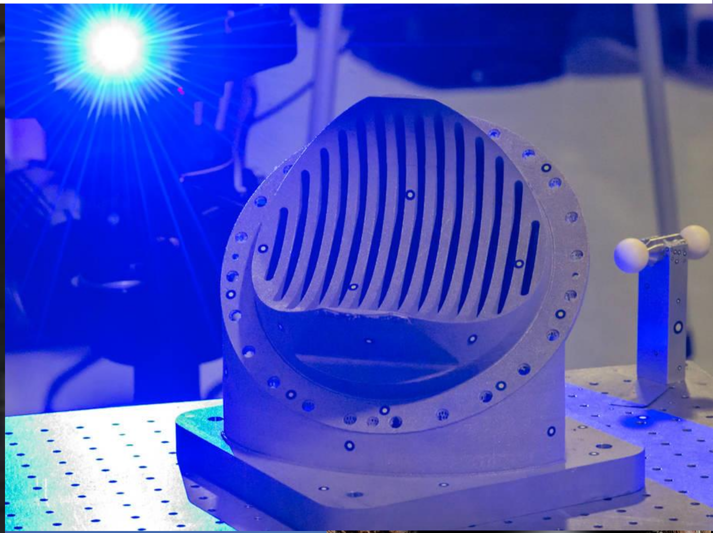
SLS

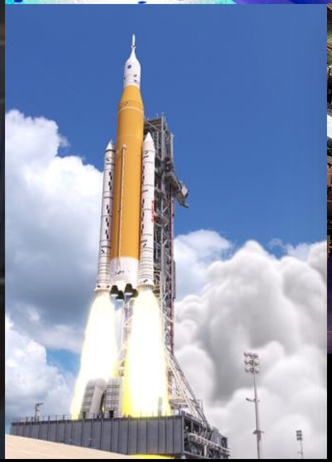
The only rocket with the power and capability required to carry astronauts to deep space onboard the Orion spacecraft

NATIONAL CAPABILITY

The SLS, Orion, and Exploration Ground Systems programs leverage more than 3,800 suppliers and 60,000 workers across all 50 states

ADDITIVE MANUFACTURING ON SLS





Successful hot-fire testing of full-scale additive manufacturing (AM) Part to be flown on SLS RS-25
RS-25 Pogo Z-Baffle – Used existing design with AM to reduce complexity from <u>127 welds to 4 welds</u>

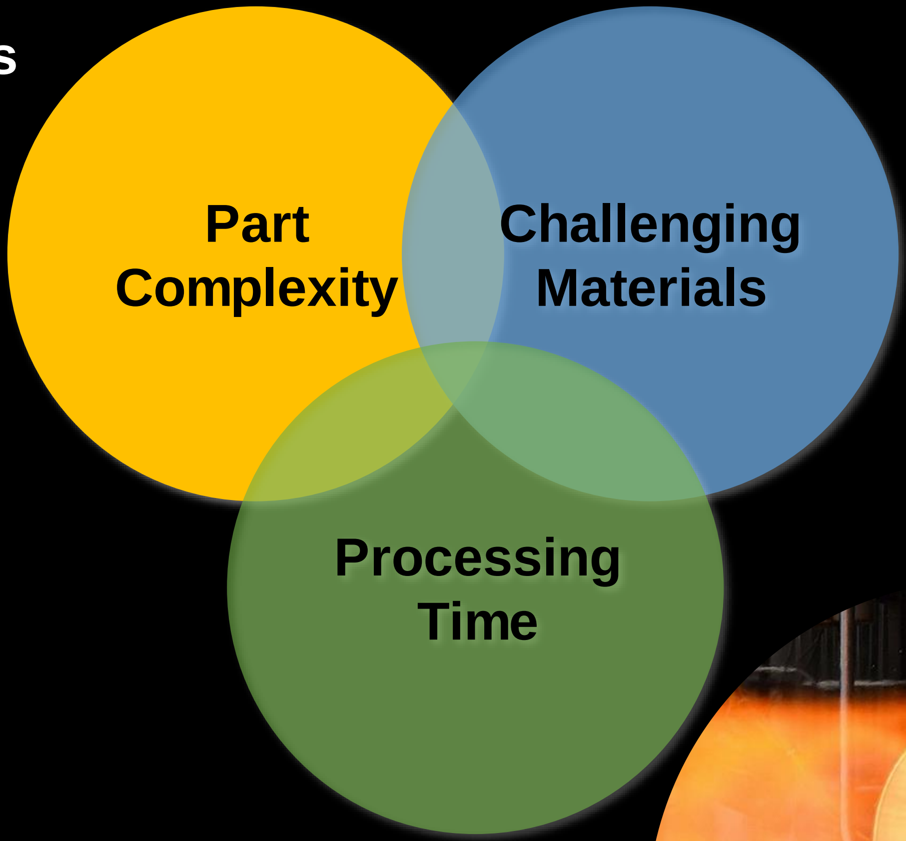
Ref: Andy Hardin, Steve Wofford/ NASA MSFC

WHY WE USE ADDITIVE MANUFACTURING?

- **Metal Additive Manufacturing (AM) provides significant advantages for lead time and cost over traditional manufacturing for rocket engines**
  - Lead times reduced by 2-10x
  - Cost reduced by more than 50%

- **Complexity is inherent in liquid rocket engines and AM provides new design and performance opportunities**

- **Materials that are difficult to process using traditional techniques, long-lead, or not previously possible are now accessible using metal additive manufacturing**



A CASE STUDY IN ADDITIVE MANUFACTURING

Category	Traditional Manufacturing	Initial AM Development	Evolving AM Development
Design and Manufacturing Approach	Multiple forgings, machining, slotting, and joining operations to complete a final multi-alloy chamber assembly	Four-piece assembly using multiple AM processes; limited by AM machine size. Two-piece L-PBF GRCop-84 liner and EBW-DED Inconel 625 jacket	Three-piece assembly with AM machine size restrictions reduced and industrialized. Multi-alloy processing; one-piece L-PBF GRCop-42 liner and Inconel 625 LP-DED jacket
Schedule (Reduction)	18 months	8 months (56%)	5 months (72%)
Cost (Reduction)	\$310k	\$200k (35%)	\$125k (60%)

PROPER SELECTION OF AM PROCESSES

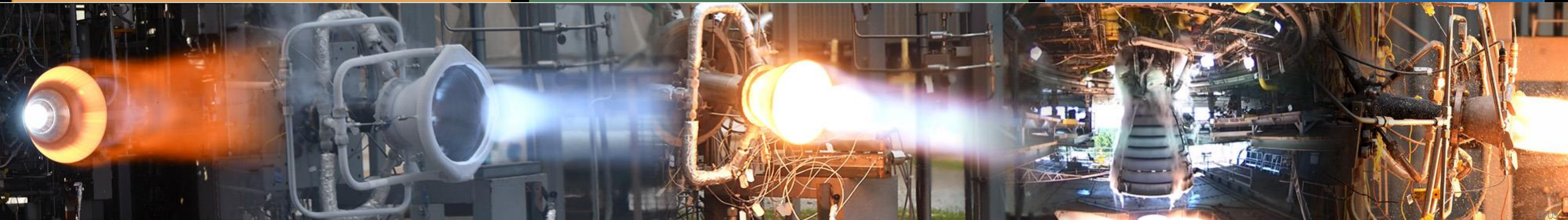
- What is the **alloy** required for the application?
- What is the **overall part size**?
- What is the **feature resolution** and internal **complexities**?
- Is it a **single alloy or multiple**?
- What are **programmatic requirements** such as cost, schedule, risk tolerance?
- What are the end-use environments and **properties required**?
- What is the **qualification/certification** path for the application/process?

ADDITIVE MANUFACTURING AT NASA

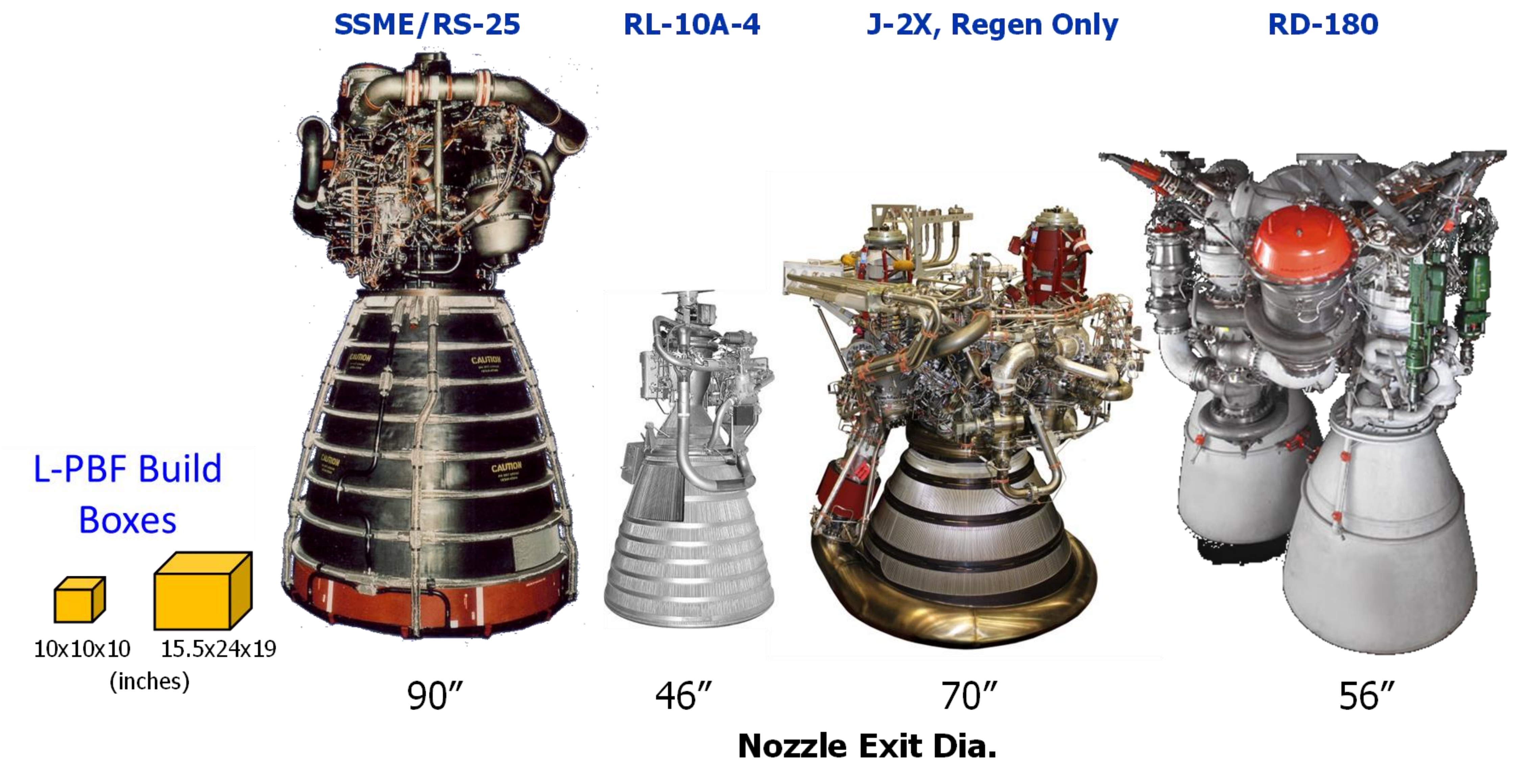
Laser Powder Bed Fusion (L-PBF) Copper Alloys combined with other AM processes to provide bimetallic

Directed Energy Deposition

L-PBF of complex components, new alloy developments for harsh environment



THE NEED FOR LARGE SCALE AM



LARGE-SCALE OPPORTUNITY FOR AM ON RS-25

With Artemis, we are landing humans on the Moon to unlock new opportunities for generations to come.